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The Evolution of Recorders for Test and Evaluation

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Recorders have always played a key role in the world of test and evaluation (T&E). In many T&E applications, data are passed in real time from a platform to a central control facility. Because datalinks can experience outages, the data are stored onboard the platform to ensure data integrity. In many cases, the datalink is not capable of passing all the data. When this occurs, only time-critical data are transmitted (while all the data are stored for post-mission retrieval and processing). This trend is graphically illustrated in *Figure 1*.

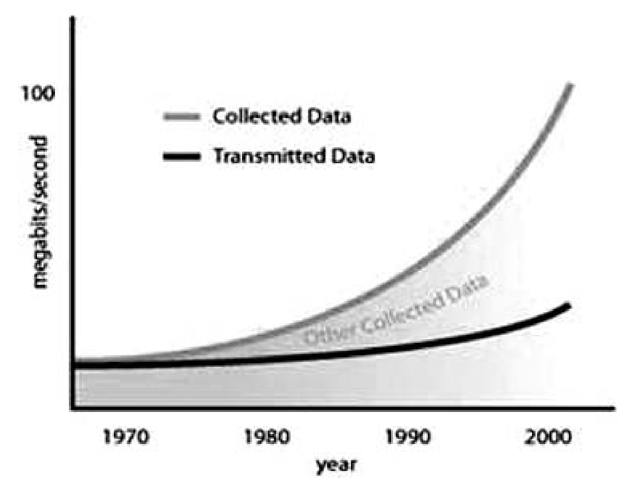

Figure 1. Graph illustrates transmission of time-critical data

Next-generation tactical aircraft will be tested using recorders that record in excess of 200 megabits per second (mbps) of data while only transmitting 5 mbps. Onboard recorders have evolved over time to meet the ever-increasing requirements of smaller volumes, operating in harsher environments, and storing larger quantities of data. Figure 1 graphically illustrates the amount of data being recorded onboard test articles, as well as the gap between transmitted and recorded data. This evolution has, for some time, leveraged commercial products typical in the commercial market. More recently, however, the T&E community has embarked on new technology to keep pace with the exponentially increasing demands for more data capacity.

In the early 1990s, small-volume recorders were made using solid-state, non-removable volatile memory with data capacity on the order of 2 Megabytes (Mbytes). These "state-of-the-art" devices required a lithium battery to maintain memory and an external computer to download the data via an umbilical cord; these two constraints greatly limited their utility. In the late 1990s, the storage media became commonly available in 220-Mbyte removable Personal Computer Memory Card International Association (PCMCIA) cards. These recording devices required no battery and were compatible with standard laptop PCMCIA ports. With the advent of high-capacity commercial products, including Smart Media, Universal Serial Bus (USB) drives and Compact Flash (CF), the test community is again turning to commercial technology to keep pace with T&E's high-capacity demands.

All of these technologies offer a significant advantage over PCMCIA cards, but CF (that is, the same devices used in digital cameras) has additional advantages, including high density, laptop compatibility and an association-controlled form factor. Current state-of-the-art CF storage is 4 Gigabytes (Gbytes) (such as that shown in *Figure 2*), but 10-Gbyte cards are just around the corner. The Test Resource Management Center (TRMC)-funded EnRAP program will employ 10-Gbyte CF cards.

Although these devices have remarkable performance, T&E data storage requirements continue to increase. In the not-too-distant future, one envisions the need to recode Terabytes of data to meet the challenge of higher sampling rates and the availability of more data types, including high-resolution video. This will pose capacity and density challenges, as well as the need for faster data read and write times. To meet these needs, TRMC is investing in a new technology, referred to as the holographic memory cube (HMC).

Figure 2. Four-Gigabyte Compact Flash card

Holographic data storage uses lasers to store information as two-dimensional (2D) "pages" of electronic patterns within the volume of special optical materials such as a photorefractive (PR) crystal. Holographic data are generated by recording the light interference pattern formed by an object laser beam carrying a page of optically modulated data (binary bits) and a reference laser beam in a cubic photorefractive crystal. Because these holographically recorded data are recorded in three dimensions and uniformly spread out throughout the entire PR crystal volume, massive redundancy is built into the holograms. The stored data will not suffer from imperfections in the media or point defects.

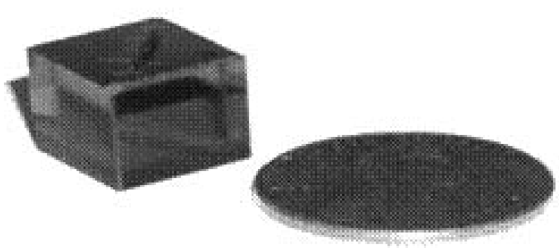

Figure 3. A photorefractive crystal cube smaller than a penny, capable of holding more than 10 Terabytes of data

Because several millions of data bits are placed on each page, and millions of pages can be stored in material the size of a sugar cube (see *Figure 3* for a size comparison), holographic systems offer the possibility of:

- Compact storage of many trillions of bytes (tens of Tbytes) of data;
- Transfer rates of billions or more of bits per second (tens of Gbits/s);
- Random access memory with single element data selection in 100 microseconds or less; and
- No moving parts.

To date, no other memory technology that offers all four of these advantages is close to commercialization.

A challenge of using these next-generation devices is that HMC technology requires a complex laser-based hologram recording and readout system. Today, this HMC input/output system is quite large, on the order of 40 cubic inches. TRMC is working with the National Aeronautics and Space Administration's (NASA's) Jet Propulsion Lab to test and advance the utility of these devices. A brassboard HMC system has been integrated, laboratory tested and field-demonstrated for holographic memory data recording and retrieval. The system consists of state-of-the-art optoelectronic devices and components. Initial test results are quite good, but much more work is required before HMC will be used in military platforms, and then in digital cameras and iPods and, well, the list is endless… ❑

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